THE AVERAGE SPECIFIC GRAVITY OF METEORITES.

In order to determine for purposes of hypothesis the density of a body formed by the aggregation of a multitude of meteorites, it is desirable first to learn the average specific gravity of those which have thus far fallen to the earth.

The writer is aware of but one attempt, the results of which have been published, to determine this quantity in a general way. These results are given in a paper by Rev. E. Hill in the Geological Magazine for 1885.[1] From Flight's "Chapters on Meteorites" this writer obtained the specific gravities of sixty-five different masses. The addition of these and division by 65 gave 4.84 as an average specific gravity. As this result took no account of the weights of the specimens, however, a recalculation was made from those whose weights and specific gravities were known, and an average of 5.71 obtained. As this sum again, however, included the great Cranbourne meteorite, whose weight of 3½ tons far exceeded that of all the rest, all masses over 250 pounds in weight were excluded. From the 52 cases thus averaged, a specific gravity of 4.58 was obtained.

Another method of arriving at the desired result was based on the ratio of metallic to stony meteorites, as they occur in the British Museum collection. This ratio is 205 stony to 55 metallic meteorites. Separating according to this ratio the 57 cases referred to, an average specific gravity of 4.55 was obtained.

R. P. Greg has also[2] found the specific gravity of about 70 stony meteorites to be 3.4. He says, however, that "as those possessing the smallest specific gravity are necessarily the most destructible and fragile, and after meteoric explosion less likely to arrive on the surface of the earth in an entire or tangible state, we may very fairly take their average density nearer the

[1] New Series, Decade III, Vol. II, p. 516.

[2] London Phil. Mag., 4th Series, Vol. VIII, p. 337.

mean of these two extremes, say, 3.0." As this density is intermediate between that of Mars, 5.3, and Jupiter, 1.4, he considers it as confirming the theory that meteorites belong to the series of planets, and have their orbits at a greater mean distance than that of the earth's from the sun.

A careful consideration of the results above quoted makes it difficult to accept any of them as final. The chief objection to Hill's results lies in the fact that there can be no assurance that the 57 cases which were listed by Flight, represented the average constitution of meteoric matter. Only an average obtained from the largest number of cases possible can be considered trustworthy, even though such an inquiry involve, as Hill states, "enormous labor of research." Again, it should be borne in mind that all the data which can at best be obtained, form but a small part of the whole, so that it is desirable that the relation of this part to the whole should be determined as accurately as possible. Daubree has calculated[1] that the fall of a meteorite on some portion of the earth is a phenomenon of daily occurrence, yet the number of *observed* falls during the past century has averaged not over one for every four months. This gap between possible and observed falls, due, of course, to the fact that a large portion of the earth's surface is covered by water, or is uninhabited by persons capable of intelligent observation, makes the collection of as large a number of data in regard to observed falls as possible, desirable.

It is only, however, during the present century that any systematic record of meteorite falls has been made at all. To include specimens preserved from earlier falls, is, therefore, likely to weaken rather than strengthen the probability of accuracy in the average.

Again, it seems incorrect to include any meteoric "finds" in obtaining data for the desired average. The stony meteorites, owing to the oxidation of the metallic grains which they contain, and the easy decomposability of olivine and others of their mineral

[1]Annales des Mines, 1868.

constituents, disintegrate and decay far more rapidly than the metallic. The metallic meteorites are, therefore, likely to be found long after stony ones of their time have gone to decay. The unusual weight of the metallic meteorites, moreover, and the silvery appearance of their interior, often lead to their being picked up and preserved where the stony meteorites escape observation. That the metallic meteorites are much more likely to be found than the stony, is indicated by the fact that of 263 meteorite "finds" now preserved in collections, 205 are wholly metallic, 28 largely so and only 30 are stony. To determine the average specific gravity of meteoric matter by striking an average of meteorites preserved in collections, seems, therefore, manifestly incorrect.

The amount of the correction which, according, to Greg should be made for meteoric matter that does not reach the earth in an entire or tangible state, must be at best a matter of speculation. I am of the opinion that the amount of such meteoric dust which reaches the earth is small, for few traces of it have ever been found. Since its amount is probably small and its specific gravity can only be guessed, I have thought it safe to omit it altogether from the calculation.

Considering, then, the desirability of using as many data as possible while at the same time excluding all that might be misleading, I can think of no better method of arriving at the desired result than to determine the average specific gravity of the meteorites observed to fall during the past one hundred years, this being the period within which a fairly complete record of meteorite falls has been kept. Such a method, will, of course, exclude a large number of metallic meteorites with high specific gravity, for only seven, or at most eight, of these have been known to fall within the past century. But it is not unreasonable to suppose that these may represent the proportion of iron to stone falls in all periods of the earth's history; for, as has been stated, the iron meteorites found may have endured for many centuries, while the stony ones of similar epochs have gone to decay.

Greg[1] has considered the proportion of stone to iron falls to

[1] London Phil. Mag., 4th Ser., Vol. VIII, p. 453.

be 25 to 1, *i. e.*, that 96 per cent. of all meteorites that fall consist of stony matter. Hence it may be assumed that, for 34 iron masses, for example, found, 25 times as many or 850 stone falls have taken place.[1] The ratio deduced from the falls of the last century would be somewhat higher than this, viz., 40 to 1. There is, therefore, strong reason for belief that there is normally a great excess of stone over iron falls. The alternative supposition, which has been urged by some, is that metallic falls have been more abundant during earlier periods of the earth's history than now, but there is no proof that these were not accompanied by a similar proportion of stone falls to that which now prevails.

If it be granted that the desired average can best be obtained from the observed falls of the past century, then again there must be recognized the fact that data for calculation on this basis suffer serious limitations owing to the lack of records of the specific gravity and weight of many of the falls. The specific gravity, so far as known, of most of the falls up to 1860, can be found in Buchner's catalogue,[2] but since that time analysts have been lamentably negligent in giving specific gravities in their published descriptions of meteorites. In searching for weights of falls too, one finds great scarcity of data, the records of earlier falls being most at fault in this respect. But though the amount of data obtainable is comparatively small, enough is at hand to permit conclusions of value.

Brezina's latest catalogue[3] gives 298 falls as having taken place since the Wold Cottage fall of 1795. For 175, or more than one-half of these, I have been able to find specific gravities given in some one or more of the records. These range between 1.70 for Alais to 7.84 for Cabin Creek, but by far the larger number lie between 3 and 4 in specific gravity. The average obtained from these 175 cases is 3.65.

[1] There is evidently a clerical error in his statement that 96 times as many, or 3624 stone falls may have taken place.

[2] Die Meteoriten in Sammlungen, Dr. Otto Buchner, Leipzig, 1863.

[3] Annalen der K. K. Naturhistorisches Hof Museum, Band X, Heft 3 und 4, Vienna, 1896.

As noted by Hill, however, an accurate result can only be obtained by taking into account the weights of the specimens, since a number of small weights of high or low specific gravity would considerably raise or lower an average obtained from individual specific gravities, while their effect on the density of a mass made up of large weights of nearly uniform specific gravity would be insignificant.

Unfortunately, a calculation on this basis reduces somewhat the number of cases from which an average can be drawn, since in many of the cases where specific gravity is given, no record of the weight of the meteorites can be obtained. By considerable searching, however, I have been able to obtain records of 142 falls, the specific gravity and weights of which are known. These include, fortunately, all but one of the metallic meteorites and most of the larger falls, such as Weston, Juvenas, New Concord, Estherville, Mocs, Alfianello and Winnebago county. By reducing these weights to the unit of water, adding and dividing, an average of 3.69 is obtained for the whole, a result nearly in accord with that deduced from the specific gravities alone.

It is possible that from records of a larger number of falls, a slightly different average might result, but it seems fair to assume that the difference would not be more than .2 or .3 from the figures given. Until further data are at hand, therefore, the value of 3.69 may be regarded a fair one for the average specific gravity of the meteoric matter which has come to the earth within the period of intelligent human observation.

To determine the probable density of a body formed by the aggregation of such matter is not a part of the purpose of this article, for this involves elaborate considerations of the effects of pressure. The present investigation has at least shown how desirable it is that those who in the future publish descriptions of meteorites should take pains to determine the specific gravity and weight of each fall. The accurate statement of these will be of great service in further investigation.

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